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I, JULIE BILLINGSLEY, TEAM LEADER EXAMINATION SUPPORT AND SALES hereby certify that annexed is a true copy of the Provisional specification in connection with Application No. PS 3247 for a patent by MARINE RESEARCH FREMANTLE PTY LTD as filed on 27 June 2002.

I further certify that the name of the applicant has been amended to SEAPOWER PTY LTD pursuant to the provisions of Section 104 of the Patents Act 1990.

I further certify that the above application is now proceeding in the name of SEAPOWER PACIFIC PTY LTD pursuant to the provision of Section 113 of the Patents Act 1990.

COMMONWEALTH OF AUSTRALIA
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WITNESS my hand this
Seventh day of July 2003

J. Billingsley

JULIE BILLINGSLEY
TEAM LEADER EXAMINATION
SUPPORT AND SALES

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ORIGINAL

AUSTRALIA

Patents Act 1990

PROVISIONAL SPECIFICATION

Invention Title: "Wave Energy Converter"

The invention is described in the following statement:

"Wave Energy Converter"

Field of the Invention

This invention relates to apparatus for converting wave energy into a form which can perform useful work.

The invention has been devised particularly, although not necessarily solely, for harnessing ocean wave energy and converting the harnessed energy to pressurised seawater for use in any appropriate way. For example, the seawater under high pressure may be piped to shore and fed to a reverse osmosis desalination unit to yield fresh water. The salt water concentrate exiting the desalination unit, which is still at high pressure, may be fed to a turbine and the shaft power used to generate electricity.

Background Art

There have been many proposals for devices that seek to harness ocean wave energy but only a few of such devices are actually under sustained commercial development. All of the commercial devices, whether shore based, ashore or offshore, have their energy conversion to electricity with the necessary equipment located *in situ*. This means the critical components such as turbines, alternator/generators and electrical distribution infrastructure must be able to withstand the marine environment including such factors as: the force of storms, prolonged exposure to seawater, and accidental immersion in seawater. In the case of offshore devices, there is also the need for extensive undersea power cabling to bring electricity to shore. The net result is increased capital cost and decreased reliability.

It is against this background, and the problems and deficiencies associated therewith, that the present invention has been developed.

Disclosure of the Invention

According to one aspect of the invention there is provided a wave energy conversion apparatus comprising a body structure having a portion thereof adapted to deflect in response to wave action, means defining a pumping chamber adapted to undergo expansion and contraction in response to deflection of the portion of the body structure, the pumping chamber having an inlet communicating with a fluid source and an outlet, whereby fluid from the fluid source is drawn into the pumping chamber upon volume expansion thereof from the pumping chamber and is discharged through the outlet upon volume reduction thereof through the outlet.

The portion of the body structure adapted to deflect in response to wave action preferably comprises a diaphragm exposed to a body of water incorporating wave action. Typically the body of water is the ocean, in which case the water is seawater.

The diaphragm may comprise a substantially rigid central portion and a flexible outer portion surrounding the central portion.

The body structure may comprise a squat cylinder having one end closed by a base resting on the ocean floor (or on the floor of another body of water incorporating wave action) and the other end closed by the diaphragm. Typically, the outer periphery of the diaphragm is sealingly connected to the side wall of the cylinder.

Preferably, the body structure includes a first chamber adapted to contain a compressible fluid such as air. The first chamber undergoes volume expansion and volume reduction upon deflection of the diaphragm, with the compressible fluid contained within the first chamber being progressively compressed to yieldingly resist movement of the diaphragm in an inward direction corresponding to volume reduction of the chamber in response to wave pressure and to urge the diaphragm in the opposite direction upon abatement of the wave pressure.

Preferably, there are a plurality of the pumping chambers. In a preferred embodiment, there are three pumping chambers.

A valve system may be associated with the inlet and outlet of the or each pumping chamber. Preferably, the valve system includes an inlet valve adapted to open upon volume expansion of the pumping chamber and adapted to close upon volume reduction of the pumping chamber. Preferably, the valve system further includes an outlet valve associated with the outlet, the outlet valve being adapted to close upon volume expansion of the pumping chamber and to open during volume reduction only after fluid contained within the pumping chamber thereof attains a prescribed pressure. In this way, fluid is discharged from the pumping chamber is at a higher pressure than the intake pressure.

Means may be provided to selectively block operation of any one or more of the pumping chambers. With this arrangement, the diaphragm can be caused to deflect in pivotal fashion in response to wave action, with the blocked pumping chamber or chambers providing the fulcrum about which the diaphragm can angularly deflect or pivot. This arrangement may be advantageous in certain situations particularly where the ocean conditions are such that the wave action is small (such as in light sea conditions). The arrangement allows the diaphragm to angularly deflect or pivot in response to the limited wave action. Additionally, the diaphragm can be arranged to pivot about an axis transverse to the oncoming wave action, so enhancing the responsiveness of the diaphragm in conditions where wave action is limited.

The pumping chambers can be blocked in any appropriate way such as by simply closing the outlet valves thereof.

The means defining each pumping chamber may comprise a bellows structure. The bellows structure may be configured as a bellows column supporting the diaphragm.

The fluid source communicating with the or each pumping chamber is preferably liquid. Typically, the liquid comprises seawater.

Preferably, the seawater is filtered. The seawater may be filtered by way of a sand filtration system. The sand filtration system may comprise a body of sand contained in a second chamber within the body structure. The second chamber may communicate with the body of seawater in which the apparatus is immersed by way of one or more flow paths.

The body structure may further include a third chamber defining a reservoir for receiving filtered seawater from the second chamber. Filtered seawater can be extracted from the reservoir for delivery to the pumping chambers.

Preferably, means are provided for selectively displacing the diaphragm to compensate for tidal conditions. Such means may comprise an adjustable support arrangement for the bellows columns, whereby the bellows columns can be selectively raised or lowered in unison to adjust the vertical position of the diaphragm.

Preferably, a stabilisation means is provided for laterally stabilising each bellows structure. The stabilisation means may comprise a system of bracing cables connected to the bellows structure. Where there are three bellows structures, each bellows structure may be connected to each other bellows structure by way of a cable. Additionally, each bellows structure is connected to a wall structure surrounding the bellows structure by two further cables. With this arrangement, the cables extending between the three bellows structures are in a delta configuration. Furthermore the two cables extending from each bellows structure to the surrounding wall are each respectively aligned with one side of the delta configuration.

A damper means may be provided for progressively damping inward excursions of the diaphragm in heavy sea conditions. The damper means may comprise a damping bellows having a buffer surface against which the diaphragm can act upon inward deflection thereof. The buffer surface is defined at one end of the damping bellows which can expand and contract in order to move the buffer surface. The damping bellows defines a damping chamber containing a damping fluid such as water. The damping chamber communicates with a reservoir by way of a flow path which incorporates flow impedance, such that there is resistance of flow from the damping chamber as the latter undergoes volume reduction in response to forces imparted to the buffer surface through contact by the diaphragm. With this arrangement, the damping bellows limits the extent of inward excursion of the diaphragm but the permitted amount of the excursion progressively increases as the wave action increases. Once the sea conditions have abated and the diaphragm no longer contacts the buffer surface, the damping diaphragm can be returned to its normal condition upon expansion of the damping chamber. A spring means may be provided for biasing the damping diaphragm towards the normal condition and thereby progressively expanding the volume of the damping chamber. The volume of the damping chamber expands at a controlled rate governed by the rate at which the damping fluid can return to the damping chamber, the rate of return flow also being subject to flow impedance.

According to a second aspect of the invention there is provided a wave energy conversion apparatus comprising a body structure having a portion thereof adapted to move in response to wave action, means defining a pumping chamber adapted to undergo volume expansion and volume reduction in response to movement of the portion of the body structure, the pumping chamber having an inlet communicating with a fluid source and an outlet whereby fluid from the fluid source is drawn into the pumping chamber upon volume expansion thereof through the inlet and discharged from the pumping chamber upon volume contraction thereof through the outlet, the pumping chamber being defined by a bellows structure one end of which is operatively connected to the diaphragm for movement therewith.

According to a third aspect of the invention there is provided a wave energy conversion apparatus comprising a body structure having a diaphragm adapted to deflect in response to wave action, a first chamber within the body structure adapted to contain a compressible fluid such as air, the first chamber undergoing volume expansion and volume reduction upon deflection of the diaphragm, the compressible fluid contained within the first chamber being progressively compressed to yieldingly resist movement of the diaphragm in response to wave pressure and to urge the diaphragm in the opposite direction upon abatement of the wave pressure, means defining a pumping chamber adapted to undergo volume expansion and volume reduction in response to deflection of the portion of the body structure, the pumping chamber having an inlet communicating with a fluid source and an outlet whereby fluid from the fluid source is drawn into the pumping chamber upon volume expansion thereof through the inlet and discharged from the pumping chamber upon volume reduction thereof through the outlet.

Brief Description of the Drawings

The invention will be better understood by reference to the following description of one specific embodiment thereof as shown in the accompanying drawings in which:

Figure 1 is a schematic perspective view of a wave energy conversion apparatus according to the embodiment;

Figure 2 is a sectional view of the apparatus of Figure 1 showing some internal details;

Figure 3 is a view similar to Figure 2 showing other internal details;

Figure 4 is also a view similar to Figure 2 but showing the details of Figures 2 and 3 in combination;

Figure 5 is a fragmentary view showing part of a seawater pumping circuit incorporated in the apparatus;

Figure 6 is a schematic elevational view illustrating part of the seawater pumping circuit;

Figure 7 is also a schematic elevational view illustrating part of the seawater pumping circuit;

Figure 8 is a fragmentary view of part of the seawater pumping circuit showing the valve system, with the inlet valve thereof open;

Figure 9 is a view similar to Figure 8 with the exception that the inlet valve is closed;

Figure 10 is a schematic plan view illustrating a cable stabilisation system for providing lateral support to bellows structure defining the pumping chambers;

Figure 11 is a fragmentary underside perspective view illustrating in particular the cable support system;

Figure 12 is also a fragmentary underside perspective view illustrating part of the cable support system; and

Figure 13 is a schematic sectional elevational view of a damper means employed in the apparatus.

Best Mode(s) for Carrying Out the Invention

The embodiment shown in the drawings is directed to an apparatus 10 for harnessing ocean wave energy and for converting the harnessed energy to high pressure seawater. The apparatus 10 rests on the sea floor in relatively shallow waters and creates minimal environmental impact. The high pressure seawater

is piped to shore and fed to a reverse osmosis desalination unit (not shown) from which fresh water can be generated. The salt water concentrate from the desalination unit, which is still at high pressure, is then fed to a turbine (not shown) and the shaft power used to generate electricity.

The apparatus 10 comprises a body structure 11 in the form of a squat cylinder 13 having a cylindrical side wall 15. The bottom end of the squat cylinder 13 is closed by a base 17 which rests on the sea floor. The top end of the cylinder 13 is closed by a diaphragm 19. With this arrangement, an interior space 20 is defined within the cylinder 13 between the base 17 and the diaphragm 19.

The diaphragm 19 comprises a rigid central portion 21 and a flexible outer portion 23 surrounding the central portion 21. The rigid central portion 21 is in the form of a reinforced circular plate and the outer portion 23 is formed of an elastomer such as natural rubber. The elastomer is reinforced with laminating materials to enhance strength and tear resistance. The outer periphery of the diaphragm 19 is sealingly connected at 25 to the upper end of the cylindrical side wall 15 of the cylinder 13.

The interior space 20 defines a first chamber 31 which is disposed immediately below the diaphragm 19 and which contains a compressible fluid which conveniently is air. The air is under pressure to provide a lifting force to counterbalance the weight of the diaphragm 19 and seawater above the diaphragm. The air pressure is adjusted so as to maintain the diaphragm 19 at a predetermined position in calm sea conditions. In this embodiment, the central portion 21 of the diaphragm 19 is maintained at a position above the upper edge of the cylindrical side wall 15. When exposed to fluid pressure arising from wave activity, the diaphragm 19 is forced downwardly towards the interior space 20, with the flexible outer portion 23 undergoing elastic expansion.

A duct (not shown) extends upwardly from the first chamber 31 to atmosphere for delivery of replenishment air to the chamber 31, as necessary. The upper end of the duct may be incorporated in a marker buoy floating on the ocean surface.

The interior space 20 also accommodates a second chamber 32 and a third chamber 33.

The second chamber 32 is of annular configuration and is defined between an inner annular wall 35 supported on the base 17 and the cylindrical side wall 15 of the body structure 11. The second chamber 32 is filled with sand 34 which provides ballast for the body structure 11 and which also is used for filtering purposes as will be explained later. Preferably, the sand is obtained from the seabed during installation of the apparatus 10. The second chamber 32 is of a size so that when completely filled with wet sand it counteracts the buoyancy effects of the submerged structure 11.

A peripheral portion 37 is disposed around the outer side of the cylindrical wall 15 adjacent the base 17 to receive additional sand ballast material. The peripheral portion 37 is configured as an open trough which can be filled with sand dredged from the seabed.

The sand 34 contained within the second chamber 32 is used in a sand filtration system 41 for the purpose of filtering seawater which is pumped by the apparatus 10, as will be explained later.

The third chamber 33 defines a reservoir for containing filtered seawater received from the filtration system 41. The filtration system 41 includes a plurality of ports (not shown) providing communication between the interior of the second chamber 32 and the surrounding seawater in which the body structure 11 is immersed. The ports open onto the seawater through the cylindrical side wall 15 of the body structure 11. The openings are covered with screens 42 for preventing entry of objects above a predetermined size.

Hydrostatic pressure of the surrounding seawater causes fluid flow through the ports to the interior of the second chamber 32 so as to cause the sand 34 contained therein to become saturated with seawater.

The reservoir 33 communicates with the second chamber 32 by way of flow passages defined by a plurality of radially extending pipes 43. Each pipe 43 contains a one-way valve 45 that permits flow only in the direction to the reservoir 33. The one-way valves 45 are arranged to permit flow into the reservoir 33 under the influence of the hydrostatic pressure of the seawater.

The reservoir 33 may incorporate means such as baffles for avoiding surges and like flows which might otherwise hinder settling of silt and the like contained in seawater in the reservoir.

The sand filtration system 41 may also incorporate means for reverse flushing the sand filter at periodic intervals to remove debris and regenerate the filter. Such an arrangement may involve flushing pipes (not shown) extending between the second reservoir 32 and the outer periphery of the body structure 11, with the pipes being capped or otherwise closed when not in use for reverse flushing purposes.

A plurality of positive displacement pumps 51 are operatively connected to the diaphragm 19. In this embodiment, there are three such pumps and each is in the form of a bellows structure 53 configured as a bellows column. One end of each bellow column 53 is connected to the diaphragm 19 and the other end is mounted on an adjustable support 54.

Each bellows structure 53 is adapted to extend and contract in response to movement of the diaphragm 19. A pumping chamber 55 is formed within each bellows structure 53, with the pumping chamber 55 undergoing volume expansion upon extension of the bellows structure and volume reduction upon contraction of the bellows structure.

Each pumping chamber 55 has an inlet 61 which communicates with the reservoir 33 thereby to receive filtered seawater therefrom upon volume expansion of the pumping chamber 55. The inlet 61 communicates with the reservoir 33 by way of an inlet path 63 defined by inlet pipe 65. The inlet pipe 65 opens onto the upper portion of the reservoir 33 so that seawater is drawn from

the upper level thereof. This is to diminish the likelihood of drawing silt and other debris from the reservoir.

Each pumping chamber 55 also has an outlet 62 communicating with a ring manifold 67 by way of an outlet path 69 defined by an outlet pipe 71. The manifold 67 is common to each of the bellows structures 53 and communicates with the pumping chamber in each bellow structure by way of the respective outlet pipe 71.

A valve system 73 is associated with the inlet 61 and the outlet 62. The valve system 73 comprises an inlet valve 75 associated with the inlet 61 and an outlet valve 77 associated with the outlet 62. The inlet valve 75 is adapted to open (as shown in Figure 8) upon volume expansion of the pumping chamber 55 and is adapted to close (as shown in Figure 9) upon volume reduction of the pumping chamber. The outlet valve 77 is adapted to close upon volume expansion of the pumping chamber 55 and to open during volume reduction but only after seawater contained within the pumping chamber has attained a prescribed pressure. With this arrangement, seawater is discharged from each pumping chamber 55 at a higher pressure than that at which it is induced into the pumping chamber.

The manifold 67 communicates with an outlet path 81 defined by outlet pipe 83. The outlet pipe 83 is flexible to accommodate height adjustment of the manifold 67, as will be explained later. The outlet pipe 83 communicates with a pipeline by means of which the high pressure seawater can be conveyed to shore.

The upper end of each bellows structure is connected to the rigid central portion 21 of the diaphragm 19. As is evident from the drawings, the area of contact between the bellows structures 53 and the diaphragm 19 is small in order to effect a large amplification of pressures transmitted from seawater acting on the diaphragm 19 to the volume of water contained within each pumping chamber 55.

A stabilising means 91 is provided for laterally stabilising each bellows structure 53 in order to maintain substantially vertical alignment of the bellows columns. The stabilising means 91 comprises an arrangement of bracing cables 93 connected to the bellow structures 53. In particular, each bellow structure 53 is connected to each other bellow structure 53 by way of a bracing cable 95. Additionally, each bellow structure 53 is connected to the surrounding circular wall 15 by way of two further bracing cables 95, 97. With this arrangement, the cables 93 extending between the three bellows structures are in a delta configuration, as best seen in Figure 10. Furthermore, the two cables 95, 97 extending from each bellow structure 53 to the surrounding cylindrical wall 15 are each respectively aligned with one side of the delta configuration, also as best seen in Figure 10.

The stabilising means 91 includes a plurality of cable arrangements disposed at spaced intervals along the length of each bellows structure 53, as best seen in Figures 11 and 12. The cables are arranged in vertical planes in order to eliminate torsional forces.

Each cable is attached to the respective bellows column 53 at a tie point 99. The tie points 99 are in the form of hooks rigidly attached to the respective bellows section at its largest diameter.

As alluded to above, each bellows column 53 is mounted on an adjustable support 54. The adjustable support 54 comprises a height adjustment bellows structure 101 positioned between the bottom of the respective bellows structure 53 and a load bearing beam 103 disposed adjacent the inner wall 35 within the body structure 11. The load bearing beam 103 transmits load to the base 17 of the body structure 11. The various height adjustment bellows 101 are interconnected to receive a common working fluid such as seawater which operates the bellows to cause extension and contraction thereof in unison. With extension and contraction of the supporting bellows 101, it is possible to effect vertical displacement of the bellows columns 53, thereby altering the position of the rigid central portion 21 of the diaphragm 19, while maintaining it in a generally horizontal condition. In this

way, the position of the diaphragm 19 can be selectively adjusted to compensate for tidal conditions. A sensor may be used to monitor the height of the main sea level above the diaphragm 19 and to effect operation of the height adjustment bellows 101 as necessary. In this way, the undeflected position of the diaphragm 19 may be held at a constant distance below sea level regardless of tidal changes. The response time of the height adjustment arrangement is made much slower than the longest period of wave motion so as not to affect the capture of wave energy yet still allow compensation for the relatively slow changes in tidal conditions. As mentioned above, the pipeline 83 is of flexible construction in order to accommodate movement of the manifold 67 with height adjustment of the bellows columns 53.

A damper means 111 is provided for progressively damping the downward excursions of the diaphragm 19 in heavy sea conditions. The damper means 111 comprises a damping bellows 113, a spring means 114, and a buffer surface 115 defined by a rigid plate against which the diaphragm can act upon inward deflection thereof. The buffer surface 115 is at one end of the damping bellows 113 which can extend and contract in order to move the buffer surface. The damping bellows 113 defines a damping chamber 117 containing a damping fluid such as seawater. The damping chamber 117 communicates with a reservoir (not shown) by way of a flow path defined by a pipe (not shown) which incorporates by-directional flow impedances. The flow impedances are such as to allow minimal damping fluid flow in each direction. With this arrangement, the damping bellows 113 limits the extent of downward excursion of the diaphragm 19 but the limited extent of each downward excursion progressively increases as the wave action increases. Once the sea conditions have abated and the diaphragm 19 no longer contacts the buffer surface 115, the damping bellows 113 can be returned to its full extended condition under the influence of the spring means 114. As the bellows 113 returns to its fully extended condition, the volume of the damping chamber 117 expands at a controlled rate governed by the rate at which the damping fluid can return to the damping chamber, the rate of return flow also being subject to flow impedance. Generally the rate of damping fluid flow in the direction from the bellows 113 to the reservoir is made small enough that it will take many cycles of contact between the

diaphragm 19 and the buffer surface 115 before the damping fluid has been substantially expelled from the damping chamber 117.

Operation of the apparatus 10 according to the embodiment will now be described. When the sea state is calm, the apparatus 10 is submerged and there is a constant head of seawater above the diaphragm 19. The diaphragm 19 is maintained at a predetermined position by appropriate air pressure within the first chamber 31 so as to balance downward forces on the diaphragm 19 arising from various factors including the weight of the diaphragm 19 and equipment attached thereto, the restoring force of the elastomeric outer portion 23 of the diaphragm 19, the restoring forces of the bellows columns 53, the hydrostatic pressure of the calm water and ambient atmospheric pressure. As a result of the large surface area of the central portion 21 of the diaphragm 19, the absolute pressure of air need only be slightly above atmospheric pressure, typically only a few psi above nominal atmospheric pressure.

At this stage, the bellows columns 53 are substantially in the extended state and the pumping chambers 55 are filled with filtered seawater drawn from the reservoir 33. Additionally, the damping bellows 113 is also in its fully extended condition under the influence of the spring means 114, and is filled with seawater.

The passage of a small wave over the apparatus 10 causes a time varying force to be exerted on the diaphragm 19, so causing the latter to move downwardly in response to this increasing force. The large amplification of pressures afforded to the bellows columns 53 causes them to contract, closing the inlet valve 75 of each bellows column and soon thereafter causing the high pressure outlet valve 77 to open. At this stage, the maximum stroke of each bellows column 53 will occur as seawater is expelled out of the pumping chamber 55 under pressure.

The downward deflection of the diaphragm 19 causes a reduction in the volume of air contained within the first chamber 31 and a corresponding increase in the pressure of the air. The air pressure continues to rise as the diaphragm 19 is deflected until an equilibrium condition is established between the force applied by the passing wave on the diaphragm 19 and the sum of the reaction forces

exerted on the diaphragm 19 by the air pressure rise and the net restoring forces of the bellows columns 53 and the elastomer outer portion 23 of the diaphragm 19. At this point, the diaphragm 19 will momentarily come to rest at its maximum deflection and the contraction stroke of each bellows column 53 will conclude. Thereafter, the pressure on the diaphragm 19 will be unbalanced, so causing the diaphragm to reverse its motion as the force due to the air pressure is reasserted. Meanwhile, the head of water diminishes as the wave passes over the apparatus 10. The cessation of each bellows contraction causes the outlet valve 77 to close and so isolates the outlet pipe 71 from the pumping chamber 55. The expansion of each bellows columns 53 cause the inlet valve 75 to open so admitting seawater into the pumping chamber 55 from the reservoir 33. The diaphragm 19 and the bellows columns 53 return to their equilibrium position awaiting the next wave.

The dynamic response of the apparatus 10 may be adjusted over a wide range through judicious manipulation of key parameters including the total mass of the diaphragm 19 and attached equipment, the total air volume and air pressure within the first chamber 31, the displacement between the diaphragm 19 and the damping bellows 113, the pressure amplification factor between the diaphragm 19 and the bellows columns 53, the stroke volume of the bellows columns 53, the mechanical spring constant of the bellows columns 53 and the pressure set points for operation of the outlet valves 77.

During normal operation, the tidal conditions may retract by the height adjustment bellows and related systems as previously described.

As the wave height increases, there is increasing downward movement of the diaphragm 19 during each wave cycle and so as a progressive reduction in the clearance between the underside of the diaphragm 19 and the buffer surface 115 on the damping bellows 113. Eventually, the underside of the diaphragm 19 will contact the buffer surface 115 and exert a force on the damping bellows 113 causing it to contract. Since the damping bellows 113 is filled with damping fluid (seawater), it resists the force to an extent allowed by the compression of the

spring means 114 as well as by the flow impedances controlling the rate at which can be discharged from the damping chamber 117. The flow impedances are set to allow a gradual retardation of the excursions of the diaphragm 19 with increasing wave motion. With each contact between the diaphragm 19 and the buffer surface 115, the damping bellows 113 is further contracted and additional damping fluid discharged from the damping chamber 117. In this way, progressively increasing excursions of the diaphragm 19 are allowed but in a controlled manner with deflections and stresses held to safe limits.

If necessary, additional damping may be obtained in high sea states by the temporary addition of supplementary air into the first chamber 31 for the duration of the adverse sea conditions.

As the sea state abates, the excursions of the diaphragm 19 will decrease and the diaphragm 19 will no longer contact the buffer surface 115. This will allow the damping bellows 113 to expand under the influence of the restoring force of the spring means 114. The direction of flow of damping fluid reverses and damping fluid slowly bleeds back through the flow impedance into the damping chamber 117 as the volume thereof expands. The bellows expansion thus follows the excursions of the diaphragm 19 until such time as the damping bellows 113 is returned to its fully extended condition.

During low sea states, it may be advantageous to optimise the extraction of wave energy by making the response of the apparatus 10 favour a particular direction if the wave energy is coming predominantly from that direction. Selectively throttling one or more of the high pressure outlets 62 may achieve this purpose. For example, in the case of the present embodiment where there are three bellows columns 53, if an approaching wave front is generally parallel to the base of a triangle formed by the three bellows columns, the two bellows columns 53 representing the base of the triangle could be blocked against operation and the remaining bellows only allowed to operate. This would then allow the diaphragm 19 to tilt in a pivotal action in the direction of the oncoming wave action, so enhancing the responsiveness of the diaphragm 19 in conditions of low seas.

Maintenance of the apparatus 10 may require access to the first chamber 31. An air lock (not shown) may be used for such purpose. Maintenance will also require that the apparatus 10 be deactivated. This can be achieved by blocking all bellows columns 53 by isolating them from the high pressure and low pressure lines when the pumping chambers 55 are full of seawater.

Rupture of the diaphragm 19 poses no damage to components inside the apparatus, as all materials are chosen to have high resistance to seawater. This is also aided by the absence of any electricity generation or distribution equipment as all such equipment is based on shore. In the event of a diaphragm rupture, divers may repair the diaphragm insitu using common adhesives and patches. An auxiliary barge may be required to facilitate the pumping out of the seawater and reinflation of the first chamber 31. Additionally, rupture of the high pressure line to shore poses no environmental hazard. The line may be covered for protection. In the event of mishap, the apparatus will automatically be shut down if loss of pressure is detected.

From the foregoing, it is evident that the present embodiment provides a simple yet highly effective arrangement for harnessing ocean wave energy and converting the harness energy to pressurized seawater. As the apparatus 10 rests in a submerged condition on the sea floor, it creates minimal environmental impact. The operating components within the apparatus 10 are mechanical and very simple in operation, allowing low maintenance and long life.

The apparatus thus addresses the concerns arising through many prior art devices firstly by moving all of the complex energy conversion technology on shore and secondly by reticulating energy as high pressure seawater through proven, low-loss piping technology.

Improvements and modifications may be incorporated without departing from the scope of the invention.

Throughout the specification, unless the context requires otherwise, the word "comprise" or variations such as "comprises" or "comprising", will be understood to imply the inclusion of a stated integer or group of integers but not the exclusion of any other integer or group of integers.

Dated this twenty-seventh day of June 2002.

Seapower Pty Ltd

~~Marine Research Fremantle Pty Ltd~~

Applicant

Wray & Associates
Perth, Western Australia
Patent Attorneys for the Applicant(s)

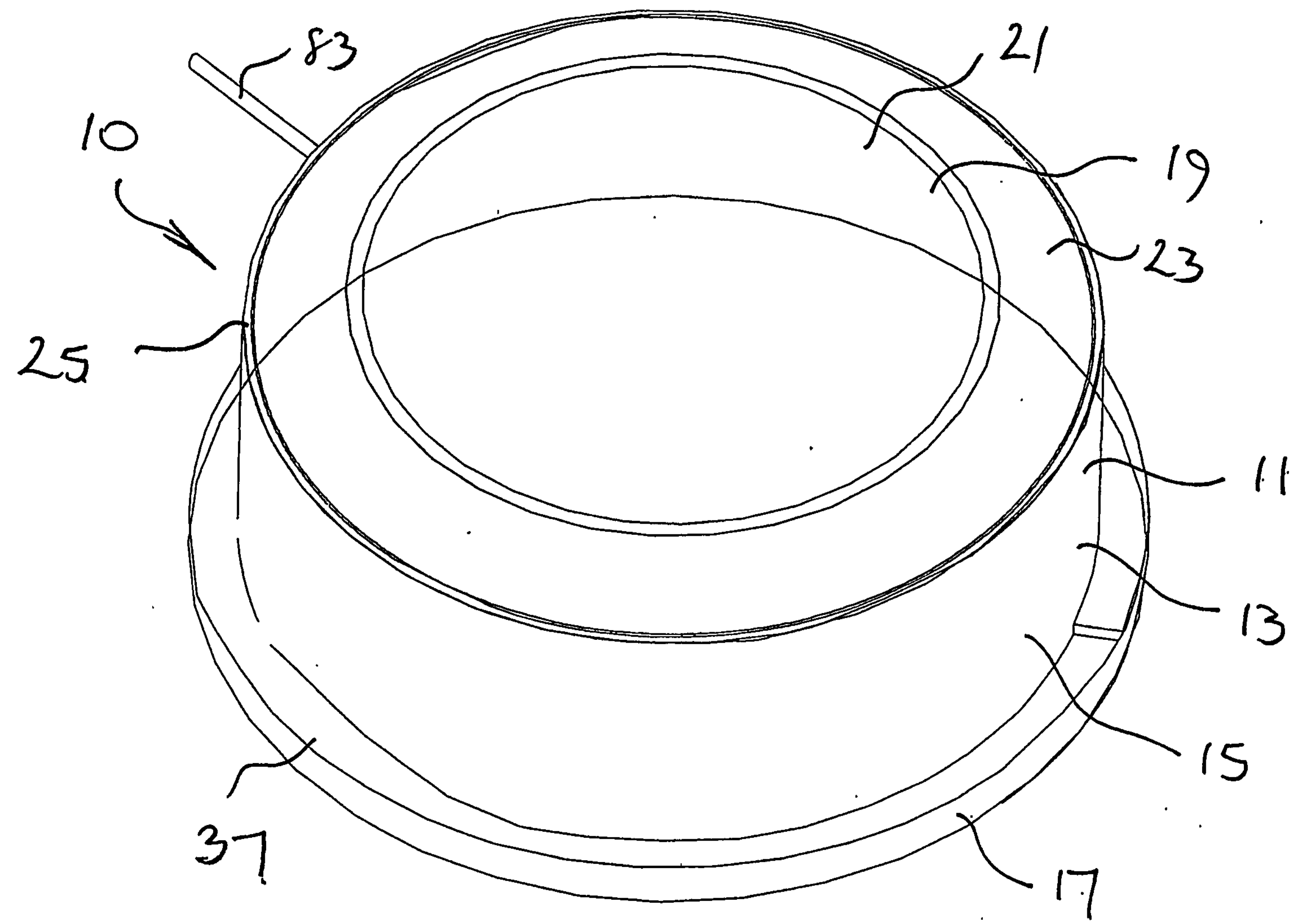

FIG 1

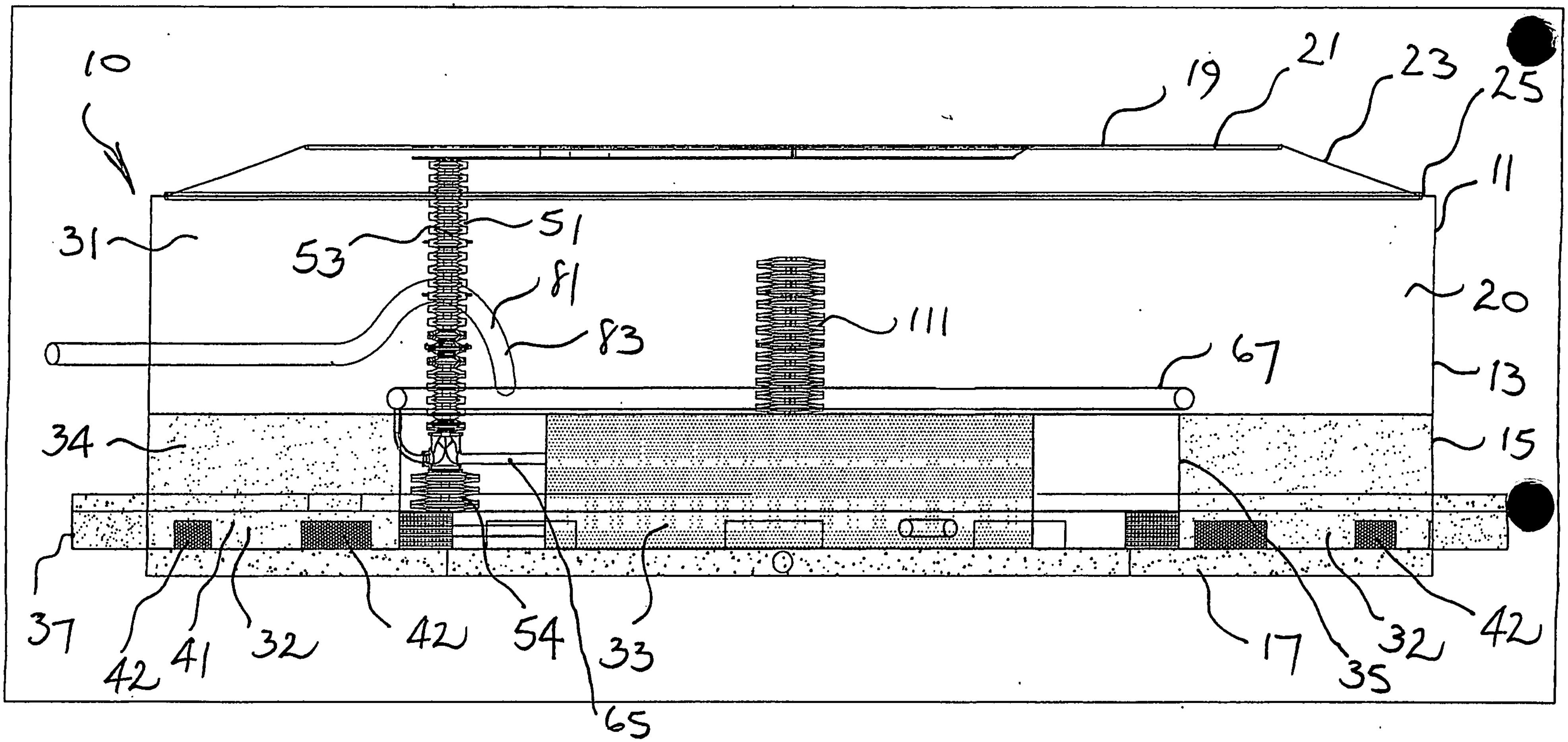

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FIG. 2

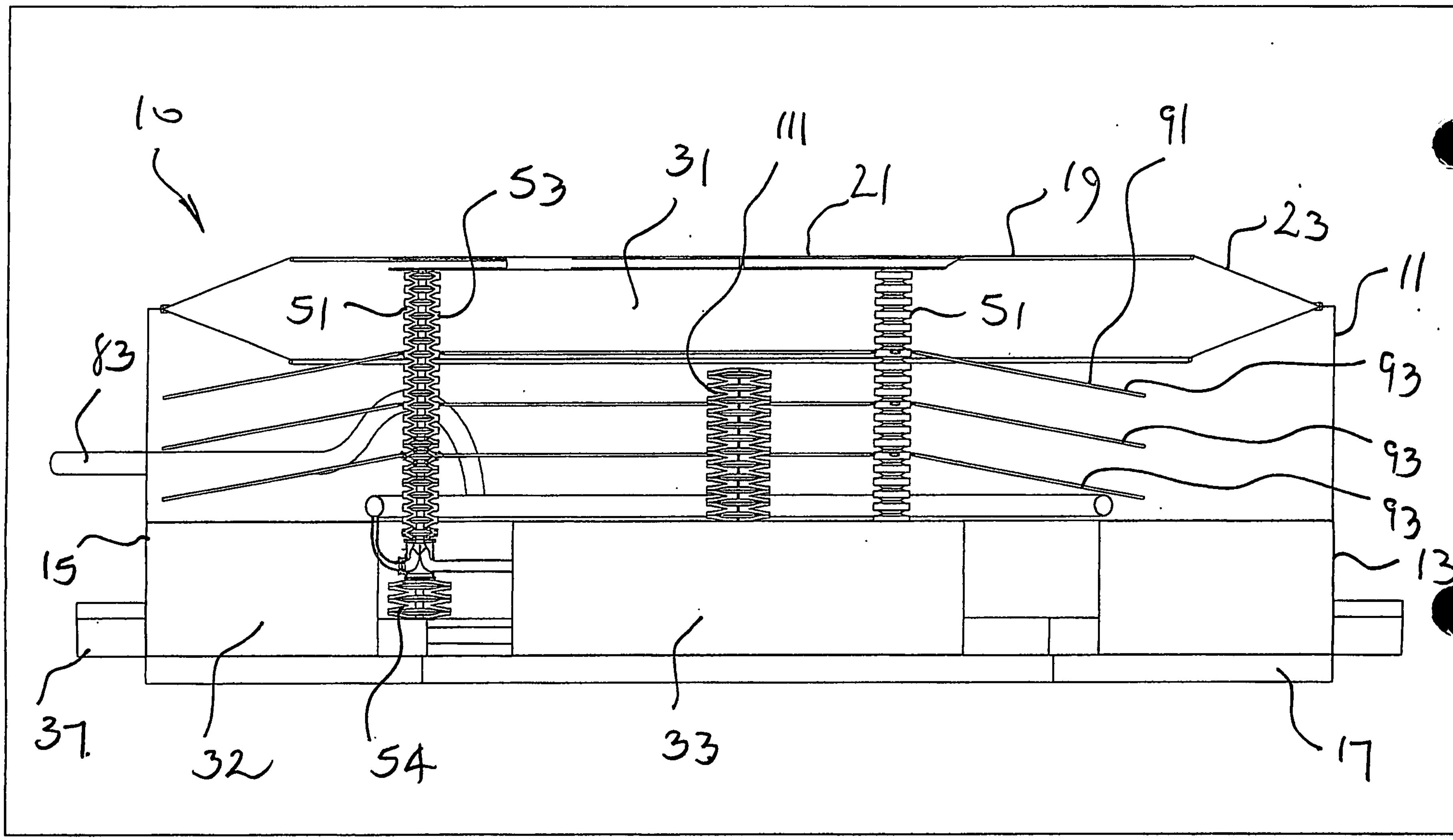

FIG. 3

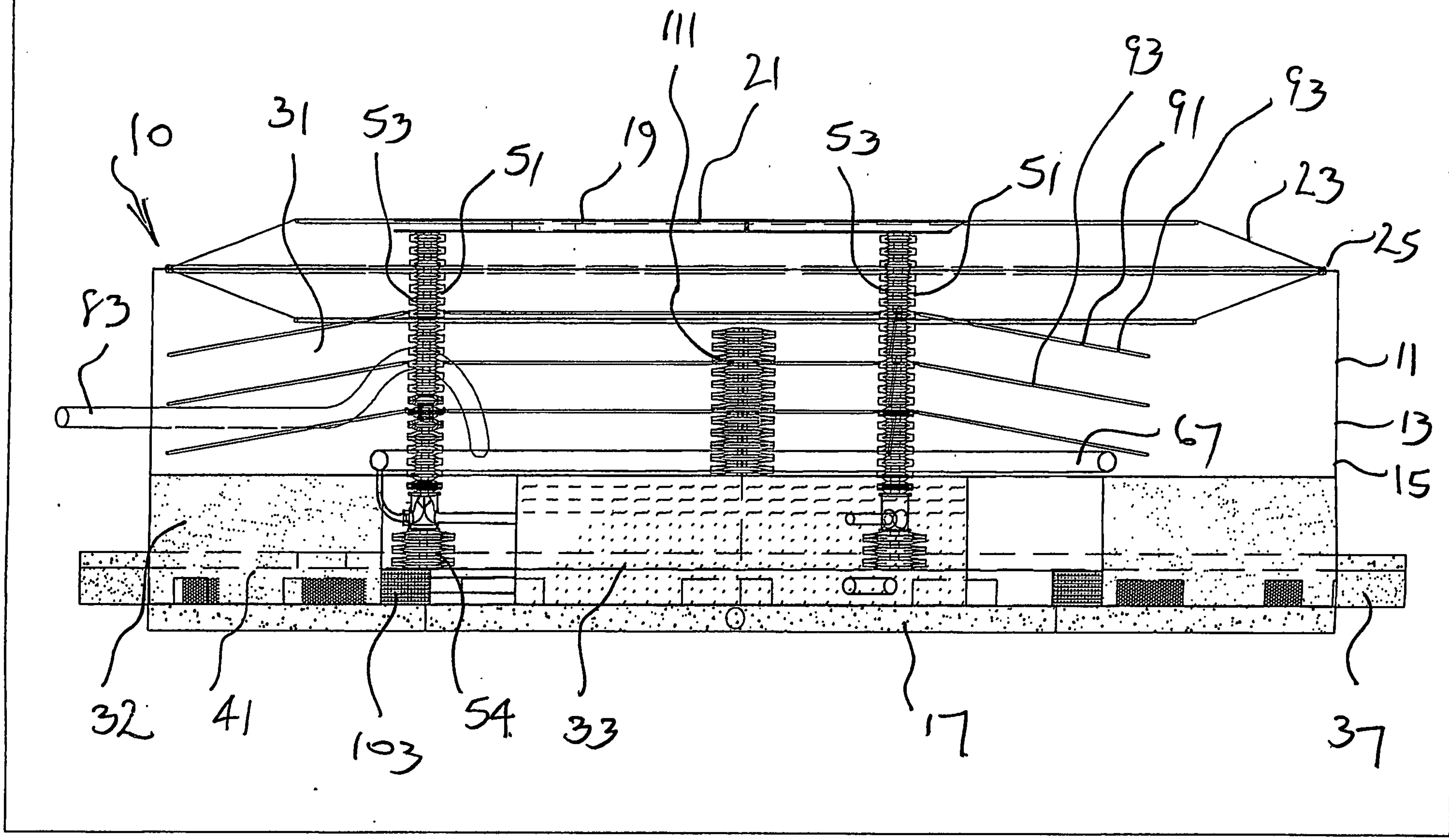

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FIG. 4

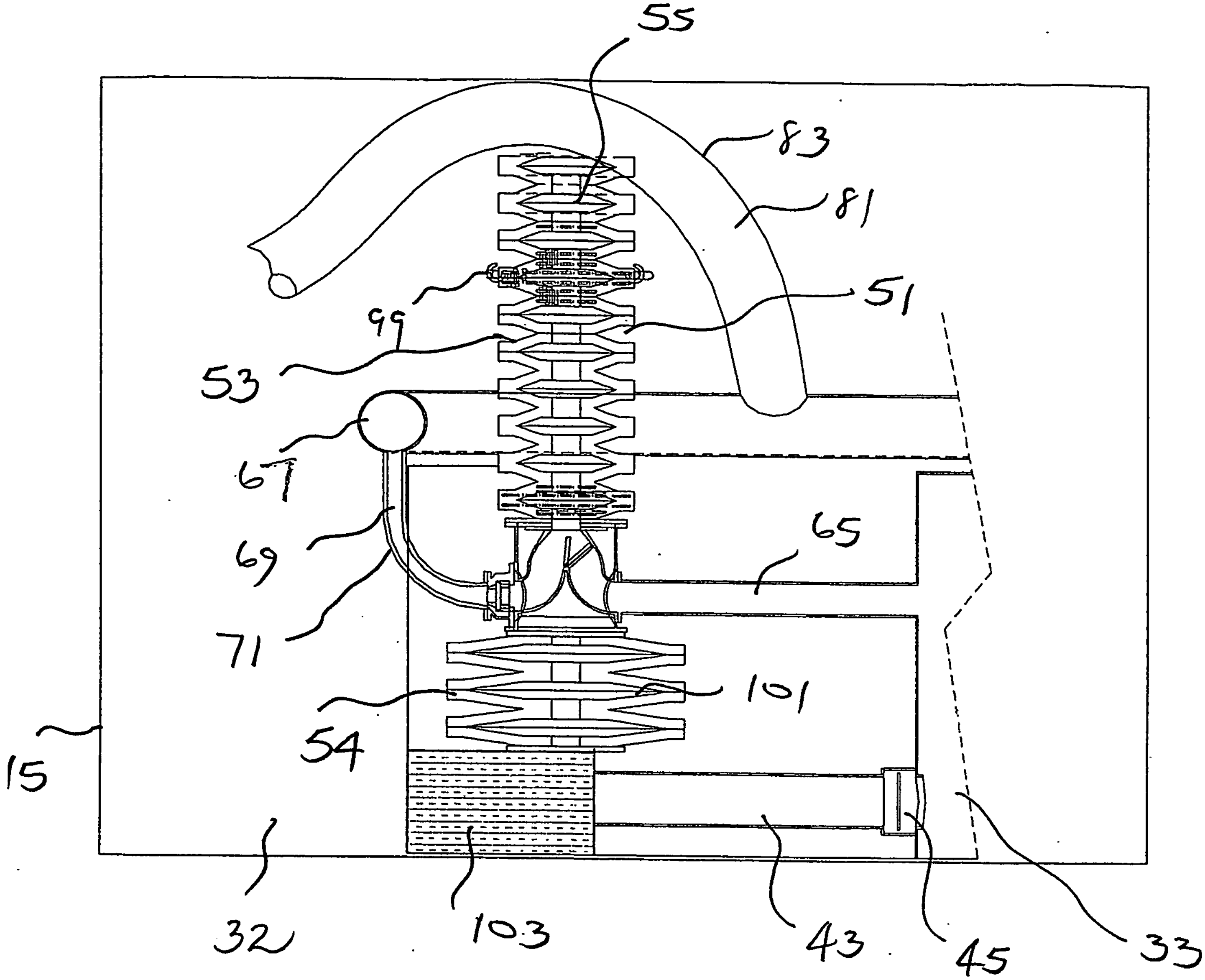

FIG. 5

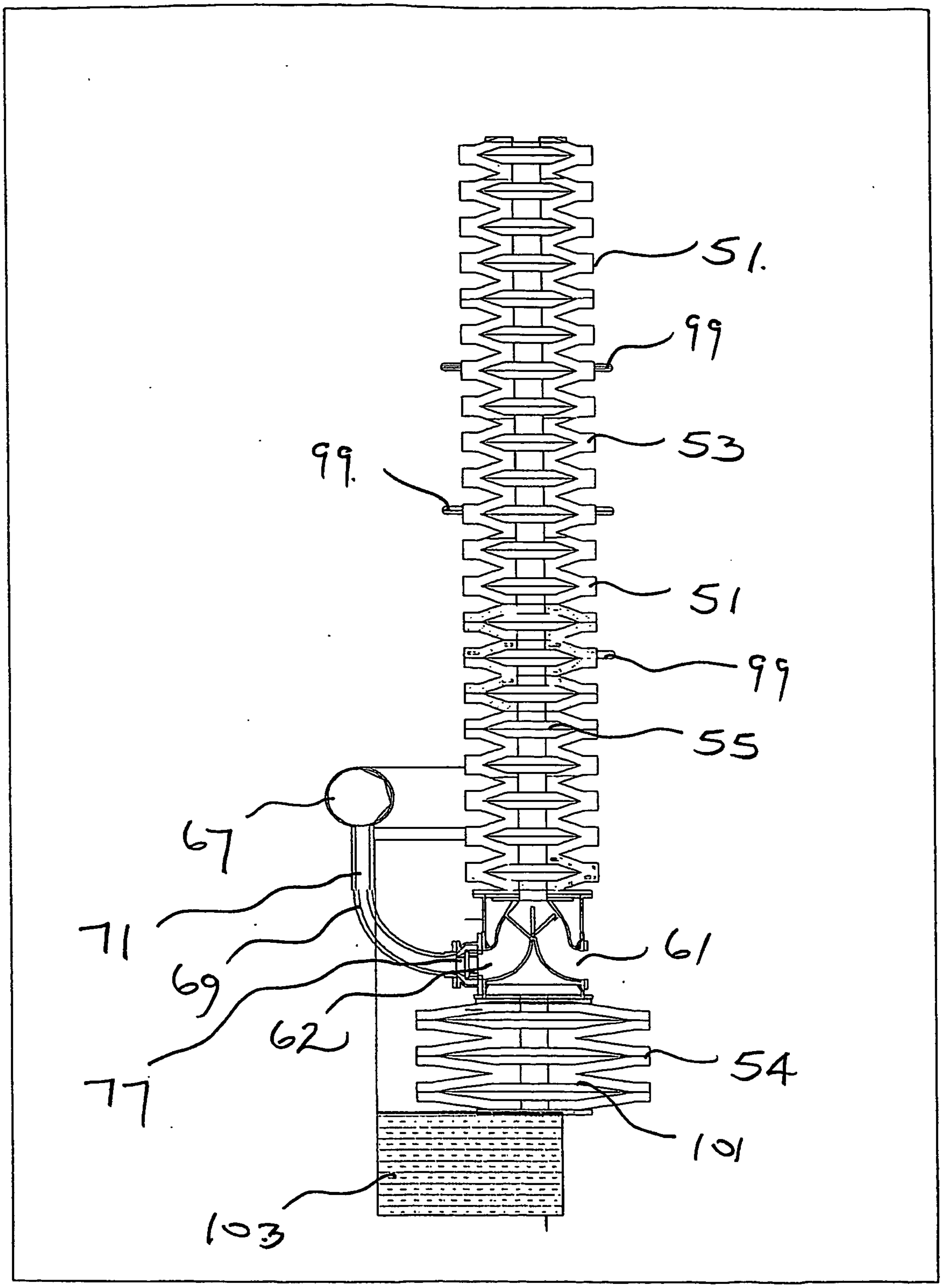

FIG. 6

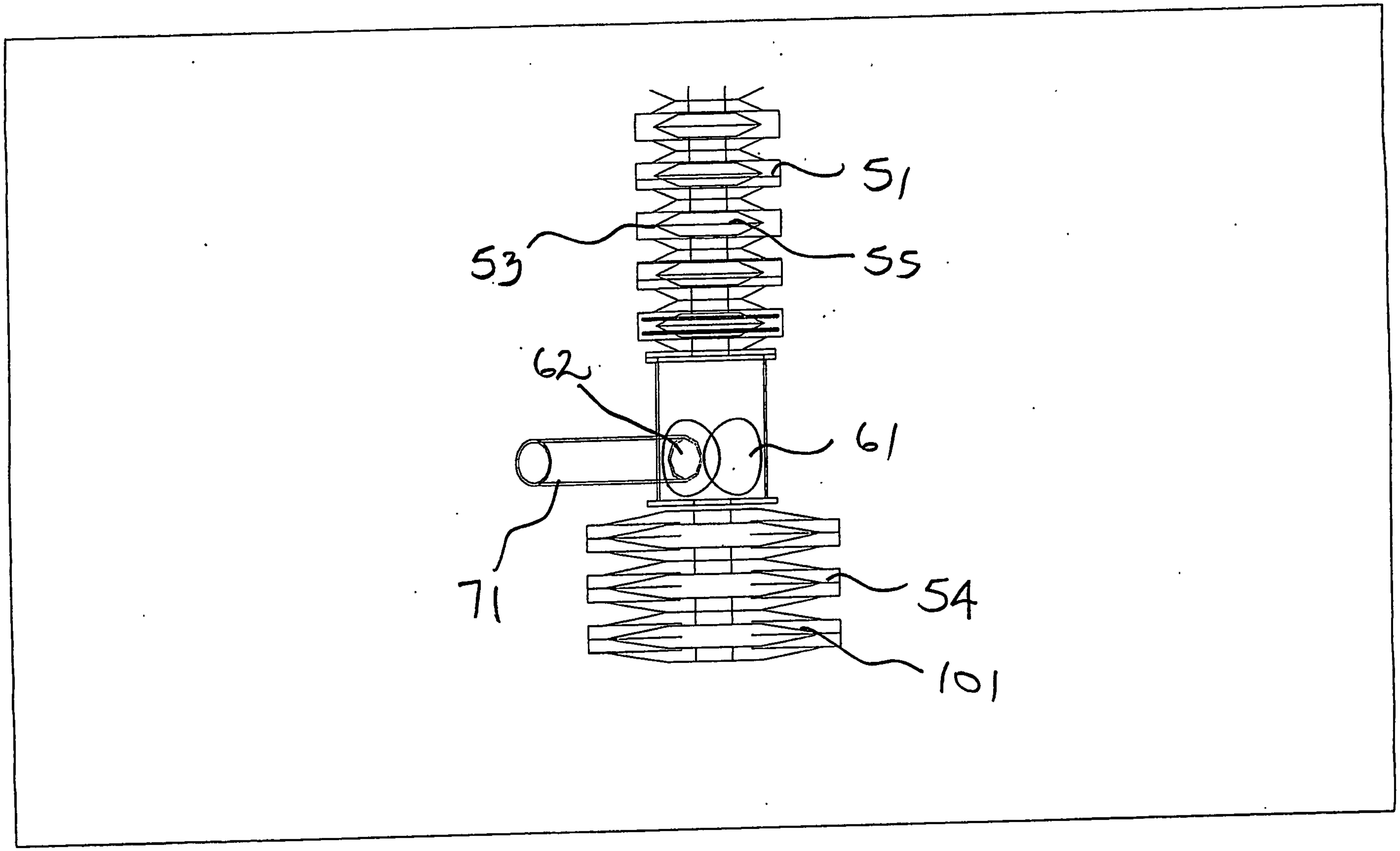

FIG. 7

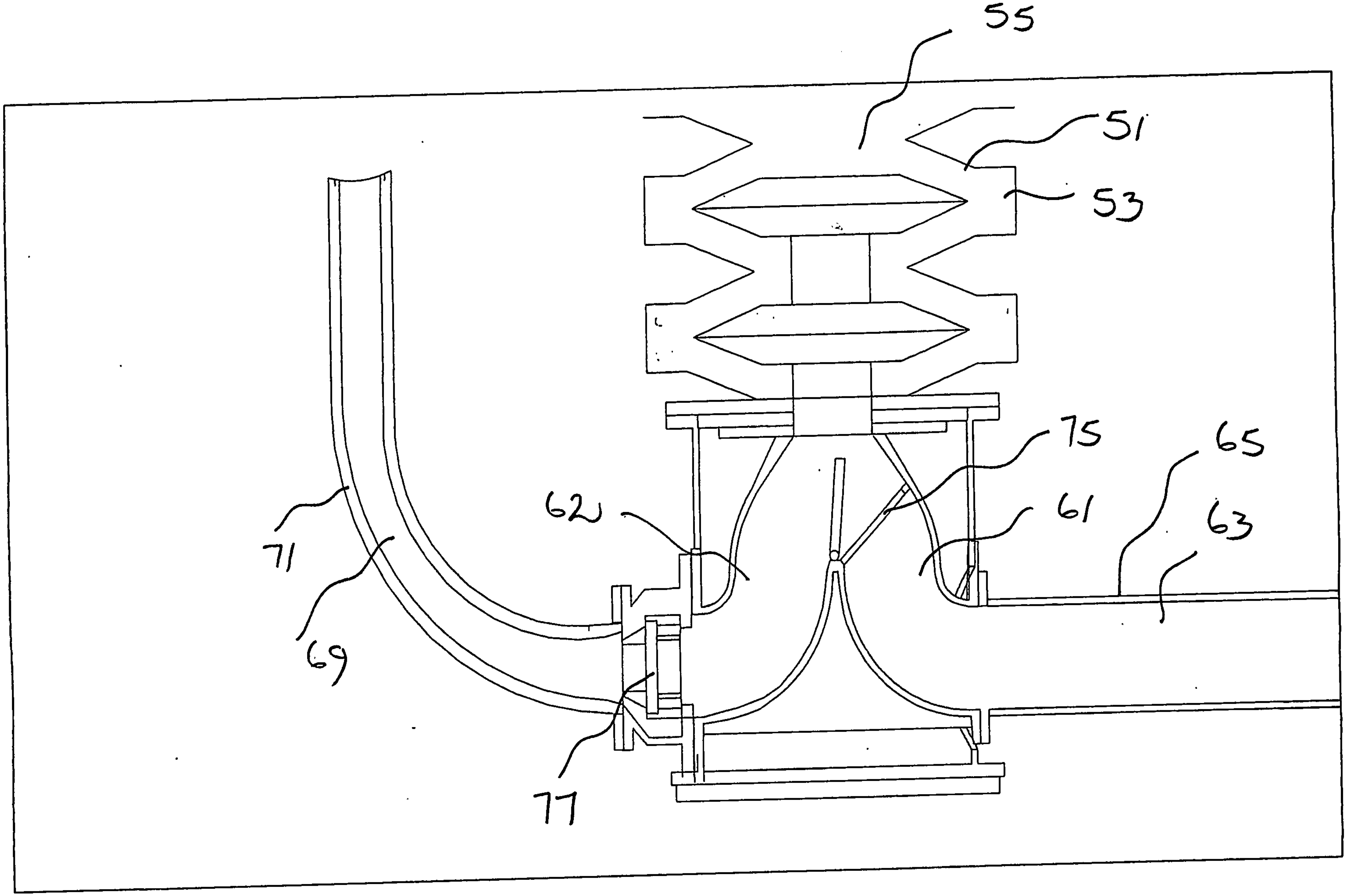

FIG. 8

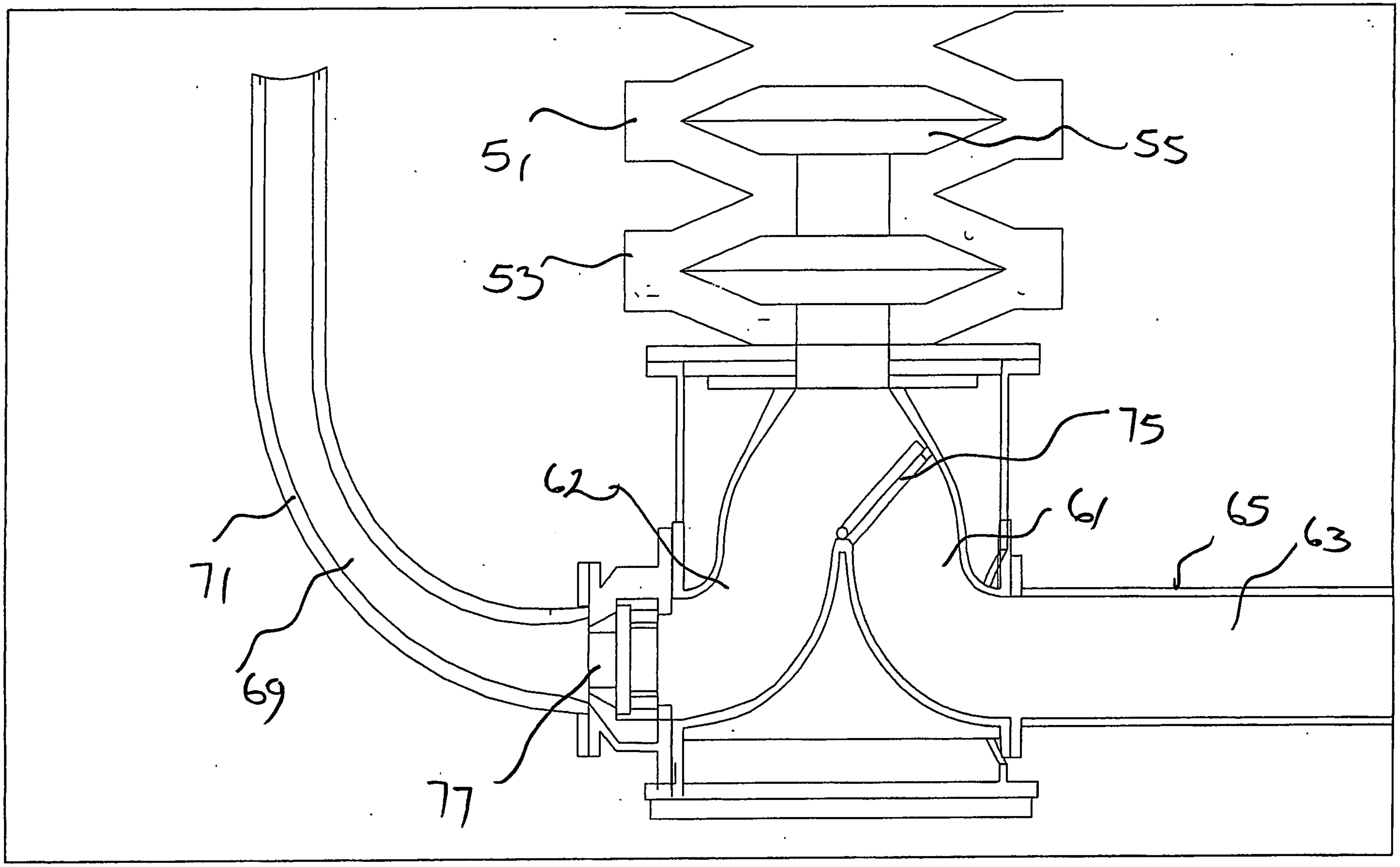

FIG. 9

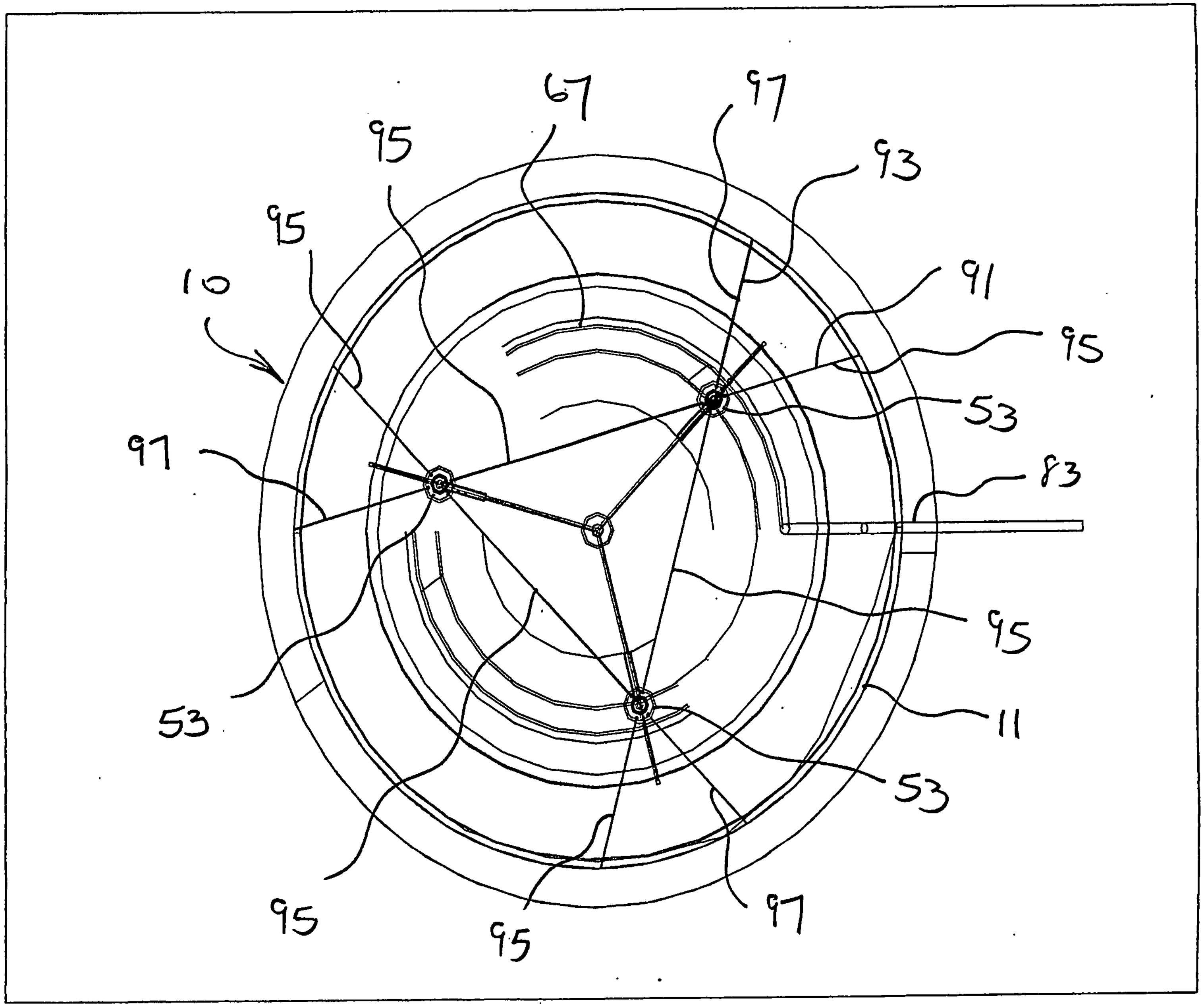

FIG. 10

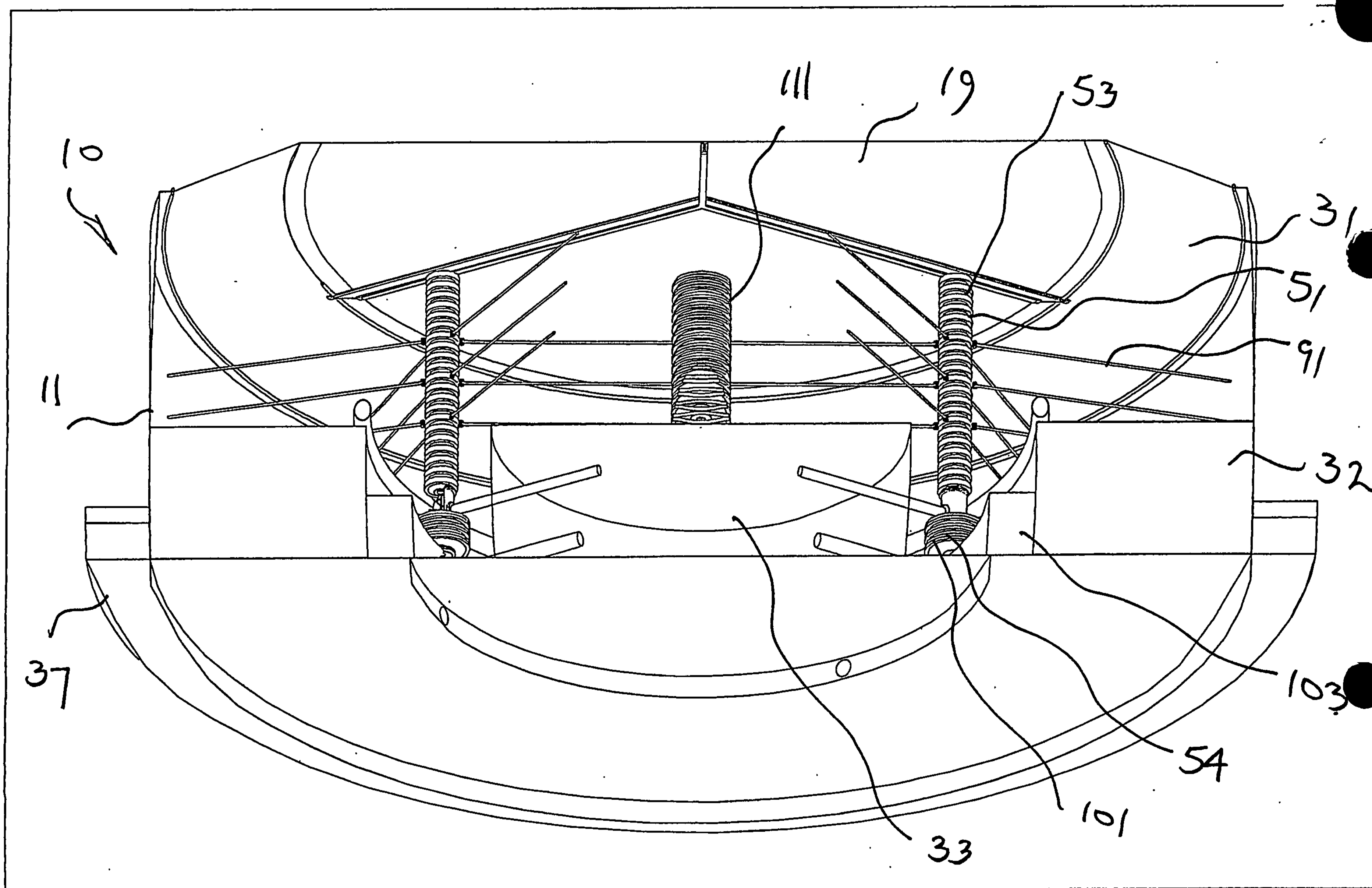

FIG. 11

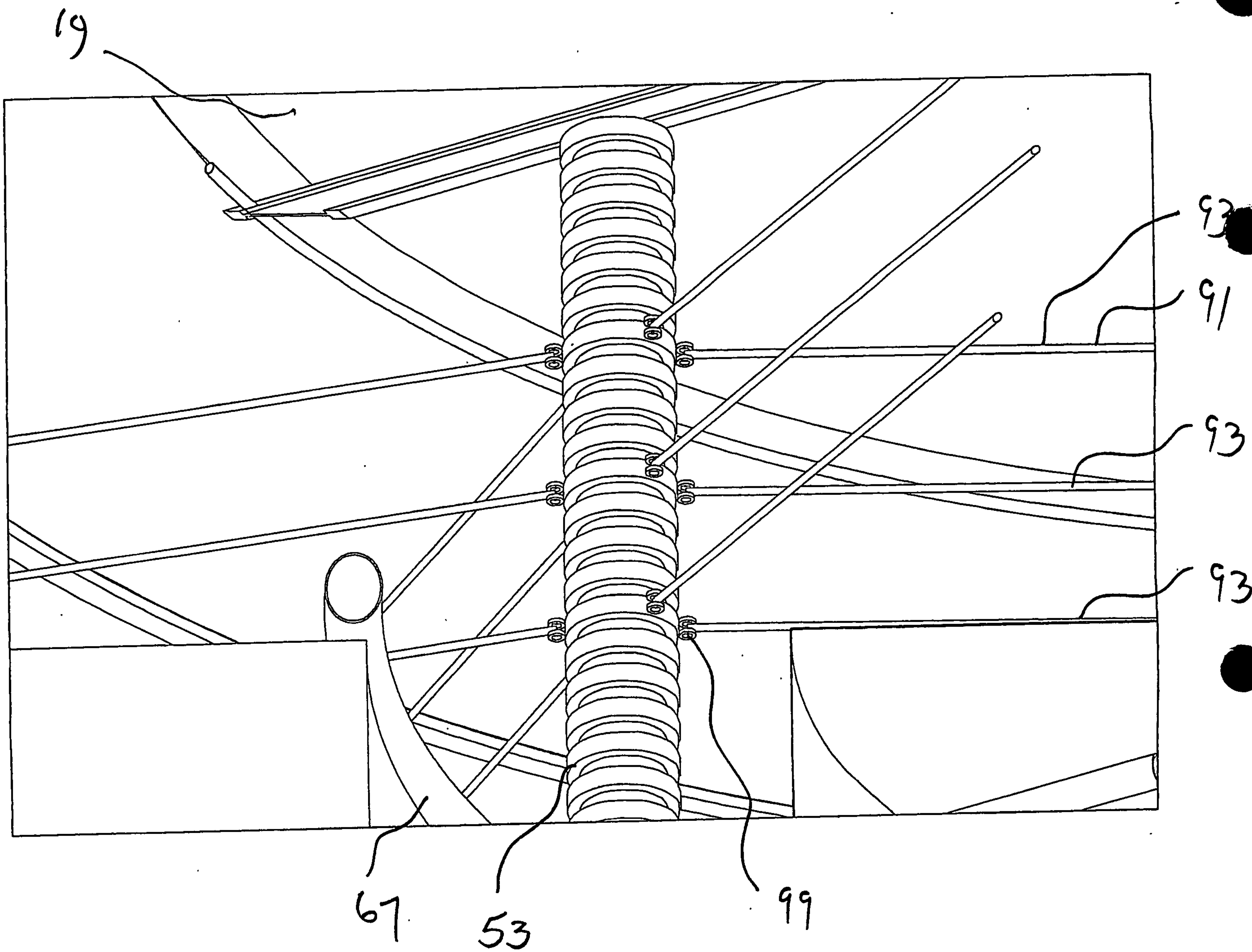

FIG. 12

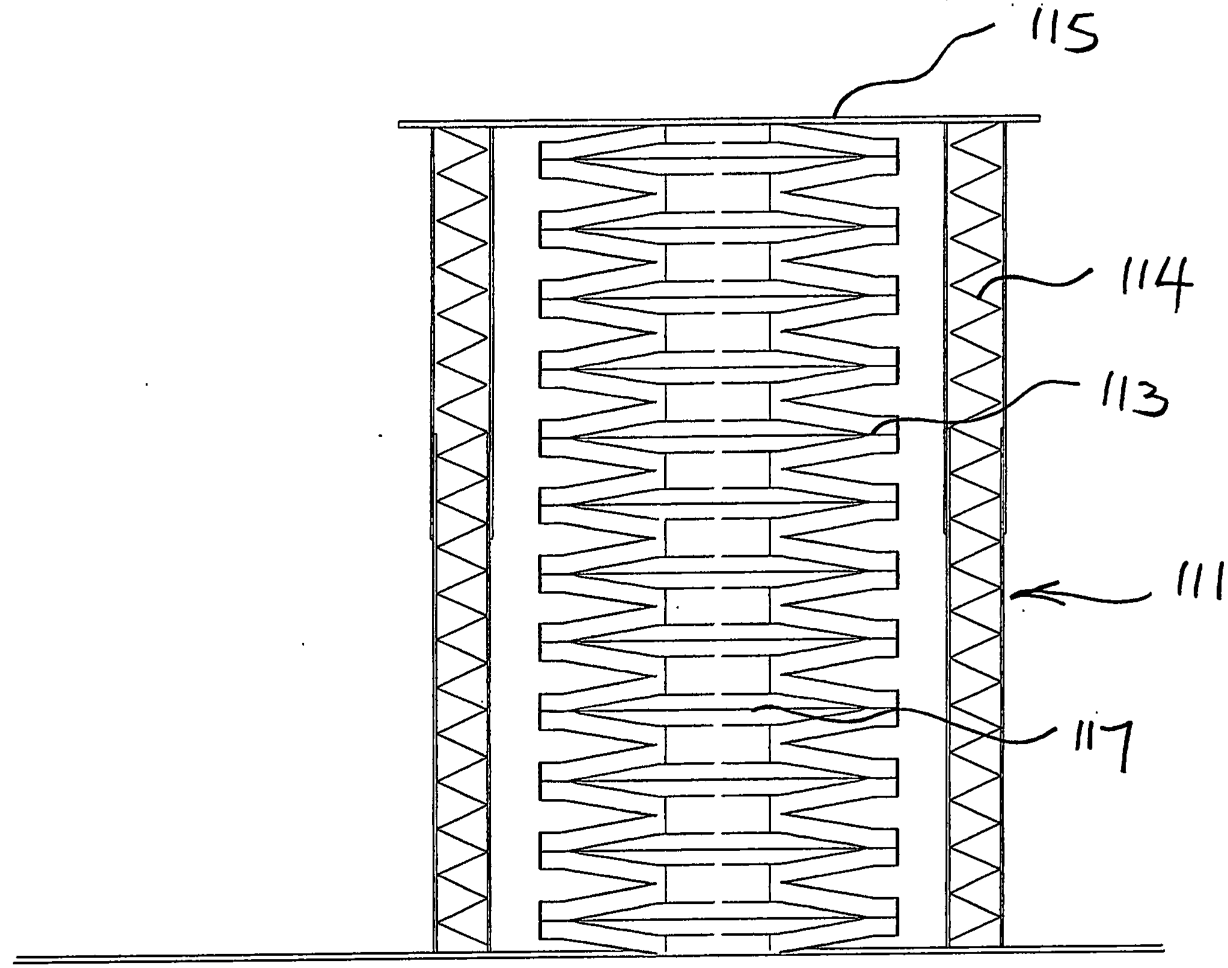

FIG. 13